U.S. Department of Agriculture Agricultural Research Service
June 1984

Agricultural Research

A New Branch on the Animal Science Tree: Ethology

The following is adapted from a speech given by Robert R. Oltjen, director of the Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, Nebr. Oltjen presented the speech at the Bureau of Animal Industry Centennial Seminar, "The Second Century of Animal Health and Well-Being," on May 29, 1984, in Washington, D.C.

Times have changed...

Decades ago, cattle, sheep, swine, and poultry were maintained in open spaces adjacent to the barn or house. The family farm consisted of perhaps an "eighty or two" of land, and a good team of horses could plow 2 acres a day.

At that time, food-producing animals, in their open environments, were subject to diseases, marginal diets, and predators; they had little protection from the elements and they were not especially productive. They did, however, have freedom of movement in their pastoral environments.

As we moved into the industrial age, farm animal production and its setting changed dramatically. No longer was cheap labor available to herd marginally productive animals until they reached adequate weights and ages. Because of labor, energy, and economic constraints, intensive production units and other systems for keeping livestock under the close scrutiny of their handlers became more commonplace. Furthermore, significant improvements had been made through research efforts to upgrade the productivity of farm animals. The result was a drastic change from pastoral settings to the more restrictive modern world and all of its new technology.

Ethology—the next step...

Although animal well-being has always been important—there's no getting around the fact that healthy and contented animals are better producers—recent heightened concern for their welfare has added another branch to the animal science tree. Ethology, the scientific study of animal behavior, coupled with physiological evaluations of stress, will set the stage for innovative management and housing methods for animals in the decades to come. Results from this research are now yielding valuable insights into the complex behavioral patterns of livestock.

For example, research by W.B. Gross, poultry scientist at Kansas State University, has shown that for chickens, adaptation to their environment is paramount to adequate growth or reproduction.

In both poultry flocks and dairy herds, rank and social dominance among animals have an impact on well-being and productivity. Research shows that social rank in cows is not directly related to milk yield, but it does affect eating and drinking habits and lying down in certain areas. And cows that receive the most licking from other cows in the same group have the highest milk yields and are at the top of the social structure.

The field of ethology is also yielding some surprising findings about animal's inherent ability to learn and participate in controlling their environment.

For example, research from the University of Illinois has demonstrated that pigs held individually or in small groups will operate a switch activating a means of supplemental heat for their environment. The pigs desired and "dialed" cool nights (73°F or 23°C) and cool summers (68°F or 20°) compared to controls subjected to 27°C (80°F) constant temperature. This resulted in a 50 percent savings in energy costs in these particular studies.

Applied animal ethology has documented some definite principles concerning the handling of farm animals. With the knowledge that livestock have 300° to 360° vision, handlers have found that solid siding on loading chutes, curved corrals, and avoidance of shadows in loading and working areas are beneficial to the animals' freedom of movement and ease of handling.

Some crystal ball forecasts...

Recent and anticipated breakthroughs in basic and applied animal research have, and will continue to profoundly affect animal production agriculture in this country. What will the future bring?

Animals in improved husbandry should show a special fit between their behavior and their environment, designed not by evolution, but by animal scientists, agricultural engineers, and applied ethologists. Management systems will be programmed to enhance an animal's contentment, and the animal's behavior will trigger the provision of whatever it needs—water, exercise, or feed. Since prime farmland will be at a premium, we may have large, subterranean dairy farms located under cities. Diets will be more scientifically advanced, and the lignocellulose bond in plants will be easily broken so that we can economically feed cellulosic residues and forest byproducts to ruminants.

Exceptional livestock will be retained as seedstock for future generations and cloning will be used routinely to perpetuate herds—perhaps for large regions.

The future looks very bright concerning the care and handling of farm animals. New findings in ethology and genetics will greatly assist us as we fulfill our ethical responsibility to understand the needs of animals, and by providing for them, assure their well-being, quality, and productivity.

Bureau of Animal Industry Centennial

What do foot-and-mouth disease, fowl plague, sheep scabies, and hog cholera have in common? They are animal diseases that have been eradicated in the United States.

This year marks the 100th anniversary of the founding of the USDA Bureau of Animal Industry (BAI), where the fight against the Nation's most devastating animal diseases began. After 69 years of existence, BAI was separated into four agencies in 1953. ARS performs animal health and production research. Protection of U.S. livestock health, meat inspection, and other aspects of animal industry are now carried out by the Animal and Plant Health Inspection Service, the Food Safety and Inspection Service, and the Packers and Stockyards Administration.

In all, BAI and its successor agencies have wiped out 12 animal diseases, helping to give the United States the healthiest livestock and most abundant food supply in the world. And we count on that supply: Foods of animal origin supply 70 percent of the protein, 35 percent of the energy, 80 percent of the calcium, and 60 percent of the phosphorus in the U.S. diet, as well as significant quantities of the B vitamins and essential amino acids.

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Vol. 32, No. 10
June 1984

Editor: Jean M. Rawson
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Agricultural Research is published 10 times per year by the Agricultural Research Service (ARS), U.S. Department of Agriculture, Washington, D.C. 20250. The Secretary of Agriculture has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department. Use of funds for printing this periodical has been approved by the Director of the Office of Management and Budget through March 31, 1987. Send subscription orders to Superintendent of Documents, Government Printing Office, Washington, D.C. 20402. Information in this magazine is public property and may be reprinted without permission. Prints of photos are available to mass media; please order by month and photo number.

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Magazine inquiries should be addressed to: The Editor, Information Staff, Room 318, Bldg. 005, Beltsville Agricultural Research Center–West Beltsville, Md. 20705. Telephone: (301) 344-3280. When writing to request address changes or deletions, please include a recent address label.

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Cover: Deep in the woods near Gainesville, Fla., technician Kenneth H. Posey aspirates a biting insect from skin treated with a candidate insect repellent. ARS and the Department of Defense are cooperating in the search for compounds that repel more kinds of biting insects than those currently available. Story begins on p. 4. (0684W771-12A)

Bye-Bye, Biting Flies

Above: Biological laboratory technician Kenneth H. Posey applies a candidate repellent to skin of technician Durward R. Godwin. Godwin will then expose his arm to insects in the cage at left to test the compound for efficacy. (0684W777-5A)

Top right: Not all candidate repellents are effective, as this laboratory test with the yellow fever mosquito, *Aedes aegypti,* shows. These insects are disease-free, however. (0684W773-17A)

What makes people flail their arms, slap their bodies, and lose all sense of decorum? Those buzzing, bedeviling, biting, bloodsucking little beasties from the insect order Diptera. Mosquitoes, black flies, biting midges, and other people-pests have provided the impetus behind a cooperative program between ARS and the Department of Defense that began during World War II. Many of the insects not only pester civilian and military populations, they transmit debilitating diseases among humans and animals.

The Organic Chemical Synthesis Laboratory at Beltsville, Md., and the Insects Affecting Man and Animals Research Laboratory at Gainesville, Fla., are continuing the search for compounds that will repel more kinds of biting insects and other arthropods for a longer period of time than deet—the active ingredient in some 30 insect repellents now on the market.

Deet was first synthesized at Beltsville by E.T. McCabe and tested at the Gainesville lab (then located in Orlando) more than 30 years ago. Although it has reigned as the #1 all-purpose repellent since then, it does have a number of shortcomings that com-

pelled chemist Terrence P. McGovern to send entomologist Carl E. Schreck more than 2,000 compounds for evaluation.

The results of their unrelenting research are a number of compounds superior to deet in several aspects. The three most promising compounds are in various stages of advanced toxicological testing at the U.S. Army Environmental Hygiene Agency (USAEHA), Aberdeen Proving Ground, Md. "They are the first compounds since deet to reach this stage of development and interest," says McGovern, referring to the interest private companies have shown in gaining an exclusive license to the patents. The patents were awarded to McGovern and Schreck and assigned to the USDA.

Like deet, the three compounds are carboxamides—each consisting of an acid and an amine portion. Throughout the history of ARS' search for insect repellents, McGovern explains, hydroxy esters, diols, and particularly amides have displayed significant repellency. He has concentrated his efforts on synthesizing these three classes of chemicals. But within these classes there are many thousands of possible compounds.

The three most promising compounds have been found relatively nontoxic in acute toxicology tests, according to Maurice Weeks of USAEHA's Toxicology Division.

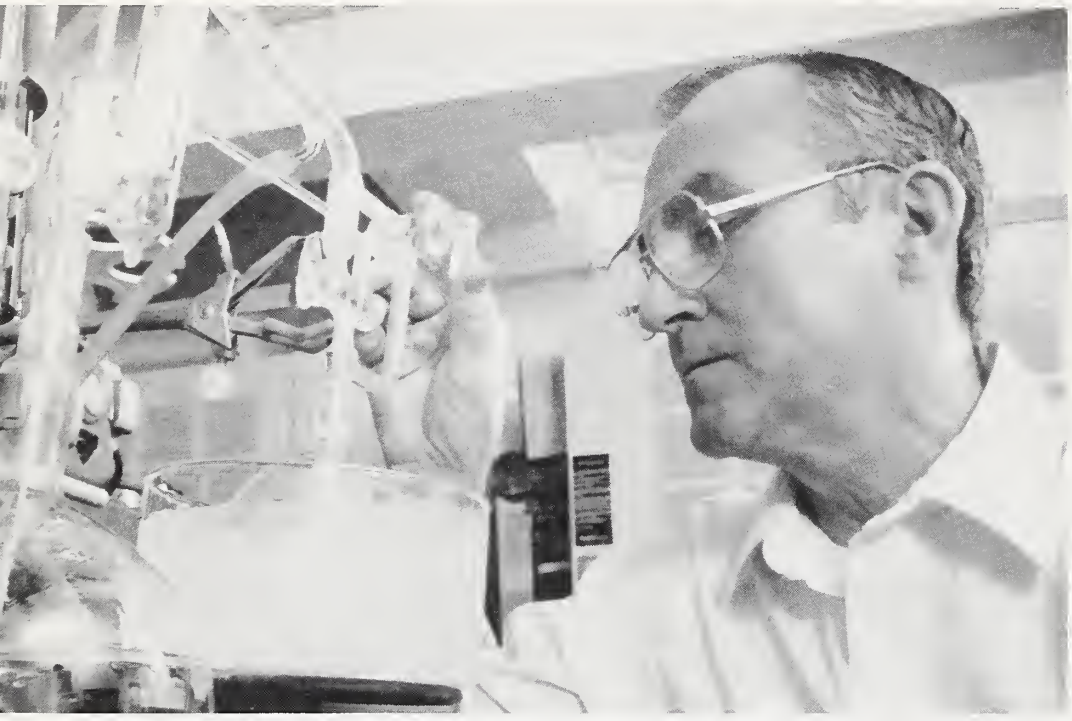
Technician Rosonald Bell rears the large numbers of mosquitos and other insects needed for extensive repellent testing. (0684W775-12)

The military places a high priority on repellent research. According to McGovern, the Armed Forces Pest Management Board is anxious to find alternatives to deet for several reasons: deet is not very effective against a number of bothersome insects—namely, black flies, deer flies, biting midges, and certain mosquito species; there is no effective backup repellent should problems arise in the manufacture or use of deet; and some troops find deet unpleasant to use. Another disadvantage of deet is that it softens or dissolves vinyl and other plastic materials. It cannot be combined with polymers—the conventional carriers for slow-release formulations—that could increase its protection time, says McGovern. Because the new compounds do not dissolve plastics as readily as deet, they are better suited for slow-release formulations.

Schreck and McGovern have given up searching for the universal repellent and conclude that all-purpose formulations of two or more compounds are probably a more realistic approach to protecting people against a broad spectrum of insects. Deet still holds the record for repelling more kinds of people-pests than any other compound, they point out. And, when all the results are in, the new compounds will probably not measure up to deet against mosquitos. But all three are far more effective than deet against deer flies, stable flies, and biting midges.

The biting midges from the genus *Culicoides* abound in coastal areas of the world, including the east and west coasts of the United States, where they breed in salt marshes and mangrove swamps. They have evoked such monikers as "no-see-ums," "punkies," and "flying teeth" from their victims and have been mistaken for various fleas, sand flies, and gnats because of their small size. Over and above their nuisance factor, they transmit a human pathogen in Brazil, are a suspected vector of Rift Valley fever in North Africa, and transmit blue tongue among sheep and other hooved animals throughout the world.

Two of the candidate compounds are more effective than deet against the saltmarsh mosquitos that plague residents and vacationers along the eastern seaboard from New Jersey to the southern tip of Florida. One of the compounds repels black flies that hound the populace in the northern tier of states and Canada—wherever there is cool, rushing water.



Synthesis and purification of insect repellent compounds is done at Beltsville, Md., by chemist Terrence P. McGovern prior to laboratory and field testing at Gainesville, Fla. (0584W529-25)

The third compound is more effective than deet against Brazilian black fly species and the true sand flies, or phlebotomines. The phlebotomines, which look like miniature long-legged moths, are scattered throughout the Americas, but are most serious in Central and South America where they transmit leishmaniasis—a severe skin disease caused by a protozoan.

Unfortunately, the new compounds are no more effective than deet at warding off some malaria-carrying mosquito species indigenous to the Western Hemisphere. But they are as potent as deet against ticks and chiggers.

During the past 5 years, Schreck and his coworkers field-tested the new compounds at several sites in Florida, and in Maine, South Carolina, Panama, and Brazil. But, he explains, additional testing is needed against both domestic and foreign species before the full potential of these repellents is known.

Before a repellent reaches this stage, however, it must qualify—and the tests are tough. McGovern assembles new compounds at Beltsville and sends them to Schreck at Gainesville. Here they compete against deet in a cloth test. Those few that make the first cut return to Maryland, but not to Beltsville. They're in the Army now, and the Armed Forces Pest Management Board sends them to Aberdeen to undergo their first toxicology tests. Maurice Weeks and company put them through an acute test phase to determine if they irritate eyes or skin or cause allergic reactions that increase with repeated use.

If the candidates prove to be relatively nontoxic, they return to the Gainesville lab for maneuvers with human subjects—again pitted against deet. Volunteers insert a repellent-treated forearm into screen cages containing thousands of laboratory-reared insects to see how long it takes before the insects will attack. Sometimes the maneuvers take place in enemy territory where the volunteers expose their treated forearms to a cloud of insects in their own habitats.

The data are analyzed to find how well each compound performed against each insect in comparison with deet. "The best measure of the effectiveness of a repellent," explains Schreck, "is the ratio of protection time versus that of a standard repellent under similar conditions." Those that show a significant difference usually last between 1 and 4 hours longer than deet, he says.

Compounds that survive these maneuvers may return to Aberdeen for subchronic toxicology tests. Weeks says that two of the compounds, which are farther along in the testing, do not cause birth defects, show no outstanding genetic activity, and fall in the moderately to slightly toxic range based on a standard toxicity rating chart. His group is now working on subchronic tests in which low doses are administered to rats for 90 days. The battery consists of feeding, inhalation, and skin studies. To determine if any of the compounds is absorbed through the skin, the toxicologists use radioactive versions of the compounds in the skin studies, explains Weeks.

Meanwhile, ARS is coordinating negotiations between the companies interested in exclusive licensing, the Armed Forces Pest Management Board, and the Department of Commerce. Although the Department of Commerce will have the final say on which company gets exclusive licensing, USDA does an initial screening to determine if potential applicants meet its own criteria for developing and marketing a product, says M. Ann Whitehead, ARS's patent specialist. When the patents are turned over to the Department of Commerce, they will be announced in the *Federal Register,* and other interested companies are encouraged to apply.

Before new products reach the market, they will have to be registered with the Environmental Protection Agency, and that will be left to the licensee, says Weeks. He explains that the Armed Forces Pest Management Board prefers that a commercial enterprise apply for EPA registration to insure that a new repellent is developed and marketed and thereby reaches all who would otherwise flail their arms, slap their bodies. . . and still have to scratch.

Terrence P. McGovern is located in Rm. 309, Bldg. 007, Beltsville Agricultural Research Center-West, Beltsville, Md. 20705, and Carl E. Schreck is located at 1700 S.W. 23rd Dr., P.O. Box 14565, Gainesville, Fla. 32604.—**Judy McBride,** Beltsville, Md. ■

The Greening of Bentonite-Mined Lands

Strip-mined lands in Wyoming, where for 30 years forage production had been nonexistent, now produce about four times as much forage as nearby virgin lands.

A key element in reclaiming these bentonite-mined areas is wood residue—a waste byproduct of the lumber industry consisting mainly of sawdust and wood chips. Mixed with mine spoil, it creates a vastly improved growth environment for plants in areas where topsoil is scarce.

"We are evaluating the use of wood residue for reclaiming bentonite-mined areas because the mine spoil is practically devoid of any organic matter, and decaying wood residue would be a readily available source," says ARS soil scientist Gerald E. Schuman at Cheyenne. "It allows the limited precipitation that the area receives to enter the soil and be stored there for plant use." And its use benefits the lumber industry as well as the soil.

Wood residue is difficult to get rid of because air pollution standards prohibit burning it in most areas. But it can become a valuable asset in reclamation because it decays in the presence of nitrogen and thereby increases the amount of organic matter in soils. Organic matter content is one of the major factors that determine soil productivity.

While nearby, undisturbed native ranges produced between 600 and 700 pounds of forage per acre, the reclamation technique developed by ARS and Wyoming state scientists converted mined areas into ranges that produced more than 2,900 pounds of forage per acre. The ranges were seeded with a mixture of introduced grasses. When seeded to native grasses, the ranges produced about 2,400 pounds per acre. In these studies, the scientists added 300 pounds of nitrogen and 60 pounds of phosphorus along with 60 tons of wood residue per acre.

"We only have 2 years' data," Schuman explains. "We may discover as our study continues that the best treatment may be 600 pounds of nitrogen per acre in combination with the 60 tons of wood residue. Wood needs quite a bit of nitrogen to hasten its decay."

Bentonite mine spoil in Wyoming. ARS reclamation techniques using wood residues have converted mine spoils such as this into productive forage land. (PN-7109)

Schuman and soil scientist Lawrence E. Woods, both at the USDA High Plains Grasslands Research Station, buried 960 small bags filled with wood residue at the test site near Upton, Wyo. They will be recovering these to monitor the rate of decay under various nitrogen treatments.

The studies are a cooperative effort between the Wyoming State Forestry Division, the Land Quality Division of the State Department of Environmental Quality, the University of Wyoming, and ARS.

State scientists involved include Carl Johnson and Tod Sedbrook, Wyoming State Forestry, and E. J. DePuit and J. A. Smith, Range Management Division, University of Wyoming.

Gerald E. Schuman and Lawrence E. Woods are located at the USDA High Plains Grasslands Research Station, 8408 Hildreth Rd., Cheyenne, Wyo. 82009.—**Dennis Senft,** Oakland, Calif. ■

The Clay of 1,000 Uses

Wyoming supplies approximately 85 percent of the world demand for bentonite. Last year, about 2½ million tons were mined in Wyoming, down from the nearly 5 million tons extracted in 1981. Because bentonite deposits lie fairly close to the land surface, strip-mining is required to extract them.

Bentonite is called the clay of 1,000 uses. Its main industrial uses are in the processing of iron ore into steel and as an ingredient in oil-drilling muds. It also is used in antacids and cosmetics.

The physical and chemical characteristics of bentonite that make it so valuable for these uses also make its spoils extremely difficult to reclaim. Bentonite spoils contain up to 70 percent clay and high concentrations of salts. When wet, the clay expands and drastically reduces the flow of water and air in root zones. When the spoil dries, the clay shrinks, cracks, and forms extremely hard crusts. The highly soluble salt concentrations are also hostile to plant growth.—**D. S.** ■

Encapsulation With Seaweed-Based Gels—A New Process

Gels derived from algin—a chemical found in seaweed—have been used commercially for some time as thickeners and stabilizers in food products, and for such specialized tasks as taking mouth impressions for dental work.

Now, thanks to a process developed by research chemist William J. Connick, Jr., alginate gels are proving to be an excellent substance for encapsulating either biological or chemical herbicides for controlled release.

The material may still be too expensive at this stage of development for commercial use. However, its use in this new gel-encapsulation process could be valuable to scientists experimenting with the controlled-release technique as an approach to solving several weed-control problems.

"This is the first time a single process can be used to make granules to prolong the release of either chemical or biocontrol herbicides," says Connick.

"Alginate gel granules can be easily prepared. The production method can be carried out at room temperature, using water as the only solvent. This is useful for incorporating into the granule a variety of chemical herbicides and also mycoherbicides—fungi used as weed-control agents," Connick says. "In alginate granules the material is incorporated throughout the entire granule, in contrast to the traditional encapsulation procedure where a core containing the active material is enveloped by a wall." In addition, the gel is biodegradable and leaves no long-term residue. Its use in food products attests to its safety.

Connick's gel-encapsulation process holds particular promise for applying mycoherbicides. Plant pathologists H. Lynn Walker and P.C. Quimby, Jr., at the Southern Weed Science Laboratory Stoneville, Miss., are the first to adapt the process for use with weed pathogens.

The scientists produce the fungus in a growth medium and then add it to the alginate solution. When the fungal-alginate mixture is added by drops to a container of calcium chloride, the droplets become gel beads that dry to make fungus-containing granules.

Walker and Quimby have found the process particularly useful for encapsulating certain fungi that form spores within structures called pycnidia. Because of the difficulty of producing pycnidium-forming fungi by conventional techniques, only a few have been studied as potential mycoherbicides. Alginate formulations may be ideal for these fungi because the spores need not be removed from the pycnidia for field application, Connick and Walker say. This may also offer better protection against adverse environmental conditions.

Another important benefit is that the encapsulated pycnidia continue to produce spores inside the granules to give a sustained-release effect. Alginate formulations of mycoherbicides can be applied directly to soil as granules, or spores can be harvested from the granules and applied as foliar sprays.

In related research at Stoneville, filaments of the fungus *Alternaria cassiae* were encapsulated in alginate gel and were shown to be effective in field tests for control of sicklepod (*Cassia obtusifolia* L.). Sicklepod is a major weed species in the southern United States that is not adequately controlled in row crops by chemical herbicides.

At the Metabolism and Radiation Research Laboratory in Fargo, N. Dak., research agronomist William W. Donald is using the encapsulation process with chemical herbicides to see if controlled release will work under no-till farming practices. Initial tests are showing good control of weeds in fallow fields in wheat-fallow rotations.

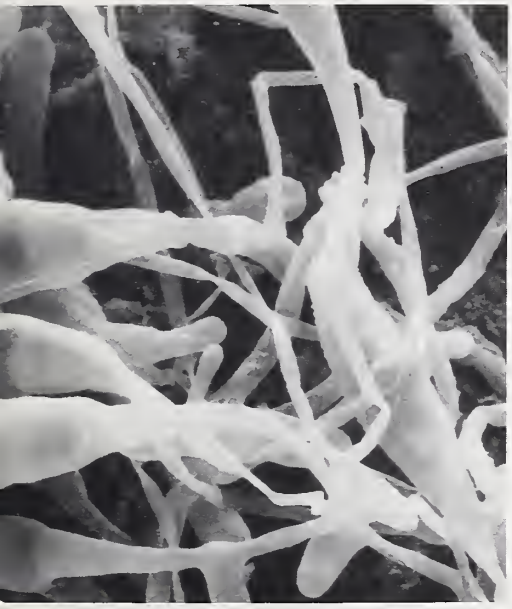
Alginate granules of chemical herbicides were tested against aquatic weeds, primarily hydrilla, by plant physiologists Kerry K. Steward and Thai K. Van at the Aquatic Plant Management Laboratory, Fort Lauderdale, Fla. In laboratory comparison tests with several experimental and commercially used formulations, alginate granules extended the life of the herbicide for the longest time.

Research horticulturist J. Ray Frank at the Weed Science Research Laboratory in Frederick, Md., is finding the alginate granules promising in tests on container-grown nursery stock. Because such stock is watered every day, a way must be found to extend the life of herbicides used on them. Encapsulation with starch xanthates is also being tested, along with commercial granules. Two years' test results indicate that both the starch xanthate and alginate compounds effectively extend herbicide life under these conditions. Testing will continue this summer.

Connick is no longer actively en-

Top: Infectious spores (conidia) of the fungus *Alternaria cassiae* magnified 700 times natural size lie near the surface of the alginate granule. The fungus kills sicklepod, a major weed in the southern United States. (PN-7111)

Miner's Disaster—Latest Biocontrol Triumph



Above: Spore cases (pycnidia) of the fungus *Phyllosticta sorghicola* (700X) isolated from johnsongrass are growing on an alginate granule. One of the cases is broken showing the mass of infectious spores inside. (PN-7112)

gaged in alginate gel formulation research, but his encapsulation process is developed to the point that other laboratories can adopt it for use at their own locations.

William J. Connick, Jr., is located at the Southern Regional Research Center, 1100 Robert E. Lee Blvd., P.O. Box 19687, New Orleans, La. 70179.—**Neal Duncan,** New Orleans, and **Jean Rawson,** Beltsville, Md. ■

Unseen, unheard, stingless wasps from Europe have overrun alfalfa fields in at least 15 states, forcing a biological change that favors farmers, consumers, and environmentalists.

The change, as revealed in recent surveys, is the suppression of a costly alfalfa pest called blotch leafminer, which also originally hailed from Europe. The imported wasps are natural parasites of leafminers.

Five years ago, ARS entomologist Robert M. Hendrickson began releasing the wasps in Delaware fields after extensively testing them under quarantine at the Beneficial Insect Research Laboratory at Newark, Del. Three of the wasp species (*Dacnusa dryas, Chrysocharis punctifaciens,* and *Miscogaster hortensis*) became established. The wasps lay their eggs in miner larvae and later emerge from the pupae, killing them in the process.

By overtaking and killing fast-spreading populations of blotch leafminers, the wasps prevent considerable damage to alfalfa. In 1978 alone, blotch leafminers caused an estimated $13 million loss in just 10 states. The wasps are dramatically reducing these losses from the Canadian Maritime provinces to as far south as Virginia, and from Delaware west to Michigan.

Alfalfa is grown on 27 million acres in nearly every state of the United States with an annual value of about $5 billion. It is the best feed crop, nutritionally, for all classes of livestock. Its leaves contain most of its high-quality protein, but are also the leafminers' primary target. As their name implies, leafminers mine tunnels in the leaves.

For 100 years, entomologists with USDA and state experiment stations have found, collected, and studied natural enemies such as parasitic wasps or predatory beetles to control major insect pests of U.S. agriculture. The work usually begins by exploring for formidable enemies in countries of the pests' origin. Before these enemies are released, scientists conduct exhaustive testing under strict quarantine to determine their environmental safety.

Well over 50 major insect pests have been fully controlled by biological control research projects and many others have been partially controlled by their natural enemies. By contrast, stopping pests with insecticides is quick and effective but provides only short-term control and must often be repeated several times each year.

The apparent demise of the alfalfa leafminer is acutely significant, says Hendrickson, not only due to swift success, but also because it is a repeat performance on a very valuable crop.

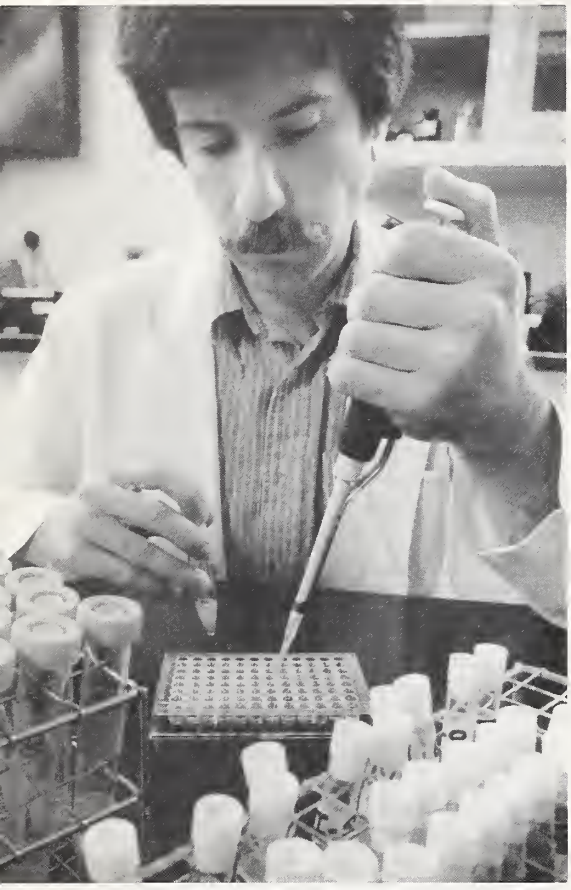
Several years ago, Hendrickson's colleague at Newark, entomologist William Day, reported that imported parasites achieved control of the alfalfa weevil in the Northeast. The weevil had become the worst U.S. pest of alfalfa, causing some $40 million in annual losses when the USDA biocontrol project began in 1959. Prior to that, 90 percent of alfalfa growers in the Northeast routinely sprayed insecticides to control pests on their crop. Now, less than 10 percent spray, says Day.

"We calculate that farmers who no longer need to spray are saving from $12 to $16 million per year in insecticides. Also, one can't fully calculate the environmental benefits involved, but before we introduced parasites, farmers used heavy applications of pest control chemicals on nearly 2 million acres of alfalfa. In some cases, this resulted in insecticide residues on alfalfa leaves and in cow's milk, kill-off of honeybees and other beneficial insects, and probably contributed to some contamination of soil and water."

The cost-effectiveness to the farmer of such biological means of pest control is matched by the economy of its development by public-funded research. For example, the cost of the USDA program to import enemies of the alfalfa weevil, including 20 years of exploration and research, was less than $1 million, or one-sixteenth of one year's savings in insecticide costs by alfalfa farmers. More important, control via natural enemies of a pest is self-perpetuating: the control agent continues to reproduce and attack the pest season after growing season.

Robert M. Hendrickson is located at the Beneficial Insects Research Laboratory, 501 S. Chapel St., Newark, Del. 19713.—**Stephen Berberich,** Beltsville, Md. ■

New Trichinosis Test—First Step to Eradication



In the final step of the ELISA test for swine trichinosis, zoologist H. Ray Gamble adds an enzyme substrate to the wells of a microtiter plate containing swine sera. A color change in a particular well will indicate the presence of antibodies and anti-parasites—signaling trichinosis infection in the pig. (0484X443-18A)

A new blood test for pigs may help strip some of the mystery from trichinosis, a disease that costs the pork industry millions of dollars in sales annually.

The test—another result of biotechnology research—can detect trichinosis-infected pigs with better than 90 percent accuracy. It has a higher level of accuracy than previously achieved without slaughtering the animal, says H. Ray Gamble, a parasitologist who developed the test with Darwin Murrell, chief of the Helminthic Diseases Laboratory, Beltsville, Md.

What caused trouble in the past, Gamble says, is that the trichina worm and certain other swine parasites are very difficult to separate by older tests. The newest test specifically detects trichina infections," Gamble says.

Pigs are the most important domesticated food animals to contract trichinosis, and occurrence is uncommon. Only about one in a thousand is believed to be infected. Even if a pig has trichinosis, thorough cooking or freezing (at $-10°$ F for 10 days, for example) will make infected pork safe to eat. A total of 29 cases of human trichinosis were reported in the United States last year. But because mild infections produce flu-like symptoms, there may be far more undiagnosed cases, he explains.

Originally, the new blood test was developed as a research tool, says Murrell, but it is now being used in ARS's national swine trichinosis epidemiology project to determine the prevalence and distribution of the disease.

Experts are uncertain about how pigs become infected with trichinosis. Some attribute infection to eating improperly cooked garbage, others to eating infected farm rats or wild animal carcasses, or directly by hog cannibalism. Trichina infections are widespread among wild animals. Over 100 species are known to carry the disease. This makes total control of the disease next to impossible in wildlife.

If the method of on-farm infection can be determined, then more effective preventive measures can be developed and employed, Murrell explains.

Another expected benefit of the test is pinpointing the geographical distribution of trichinosis. When the distribution is known, control measures can be concentrated in the most critical areas, Murrell says.

Within the pork industry, the National Pork Producers Council is coordinating a task force of federal, state, and industry researchers to seek to eliminate trichinosis in pigs by 1987.

To develop the new test, Gamble fused spleen cells from mice, previously infected with trichinosis, with mouse cancer cells. (See *Agricultural Research,* Jan. 1984, p. 8.) The resultant hybrid cells combine the spleen cell's ability to produce antibodies with the cancer cell's ability to multiply rapidly and indefinitely. In turn, the hybrid cells produce nearly unlimited quantities of pure or monoclonal antibody to the trichina worm, and only to the trichina worm. He and Murrell have applied for a USDA patent on the new hybridoma cell line.

Once Gamble produced the specific monoclonal antibody, he was able to isolate the antigen on the worm that stimulates antibody production. It is this antigen that binds to the antibody in the tested pig's blood, and, in conjunction with a dye, shows whether the pig has trichinosis.

Gamble says his next projects are a vaccine for trichinosis derived from monoclonal antibodies, and a genetically engineered antigen for the trichinosis test.

Genetically engineering bacteria for production of the antigen would ensure sufficient quantities for both vacine development and the new test if it goes into commercial use, he says.

H. Ray Gamble and K. Darwin Murrell are located in Bldg. 1040, Beltsville Agricultural Research Center-East, Beltsville, Md. 20705.—**Vince Mazzola,** Beltsville, Md. ■

Starch-Based Membranes for Dialysis

Membranes made with starch from corn or other crops can be used as filters to separate large and small molecules in a process called dialysis. These semipermeable membranes demonstrate the discovery of another property of starch, says Felix H. Otey, chemist at the Northern Regional Research Center, Peoria, Ill.

He says large molecules of substances in solution pass through the starch-based membranes slowly or not at all, and small molecules go through faster. He and fellow chemist Richard P. Westhoff found a way to make these first starch-based, semipermeable membranes in studies of biodegradable starch films. They have been granted a patent on the membranes and the method of making them.

Semipermeable membranes made from cellulose or synthetic polymers are used in dialysis now. Dialysis is used to separate toxic substances from blood in artificial kidneys, to fractionate blood, to separate proteins, and in industrial processes such as recovering lye used in manufacturing rayon. Membrane separation techniques are also used in filtering toxic wastes, producing salt and chlorine, removing salt from seawater, purifying beverages, and producing monoclonal antibodies. The starch-based membranes have not been tried in these applications, Otey says.

To demonstrate that the starch-based membranes are semipermeable, Otey tested them with solutions of urea, salt (sodium chloride), and four sugars. "The data clearly demonstrate that the starch films allow small urea molecules and sodium chloride ions to diffuse many times faster than the larger molecules of sugars," he says. Urea diffused through one membrane 7.6 times faster than glucose sugar and 32 times faster than sucrose (table sugar).

"Starch-based membranes can be tailored for specific permeability characteristics," Otey says, by adjusting the proportions of starch and a polymer of ethylene and acrylic acid. Semipermeable membranes can be made with starch-to-polymer ratios ranging from 20:80 to 60:40. "Below 20:80, the permeability to even the smallest molecules becomes insignificant," Otey says. The preferable starch-polymer ratios range from 30:70 to 50:50.

The new membranes are transparent, which indicates an even distribution of starch throughout the membranes, he says.

Efforts to achieve uniform starch distribution in starch-based plastics for agricultural mulches and packaging films led to discovey of the new semipermeable membranes. Otey says he and colleagues successfully prepared the agricultural films, which are not permeable, by combining starch, ethyleneacrylic acid polymer, ammonia, and water.

"When we used sodium hydroxide, a strong alkali, in place of ammonia," he says, "we found the films to be much more transparent and quite permeable to small molecules."

Felix H. Otey is located in Rm. 2112A, Northern Regional Research Center, 1815 N. University St., Peoria, Ill. 61604.—**Dean Mayberry,** Peoria, Ill. ■

Research leader Felix H. Otey demonstrates how starch-based membranes discriminate between small and large molecules. A solution of sodium hydroxide—a common alkali having small molecules—is above the membrane bisecting the cylinder. As sodium hydroxide molecules pass through the membrane they turn an indicator—phenothaline—in the lower compartment red. But because phenothaline molecules are too large to pass through the membrane, the upper compartment remains clear. (0584X702-10A)

Starch can be combined with a synthetic material to produce hybrid dialysis films. As a starch-plastic tube emerges from the extruder, chemist Richard P. Westhoff pinches the top allowing air from the extruder to expand the tube into a balloon. The balloon will be cut into hybrid films. (0584X704-27A)

Cablegation Makes the Grade

To minimize soil erosion, agricultural engineer James Ayers has installed specially shaped nozzles to dissipate the force of water as it flows into furrows from the cablegation system. (1083X1480-19)

The automated surface irrigation system designed for growers needing a low-cost alternative to sprinkler systems—cablegation—is now being tested on land with little crossfield slope. If successful, the way will be open to use this system in the nation's top irrigated state—California.

As originally designed, cablegation is an energy-saving irrigation system that depends on gravity. It delivers water to furrows automatically and sequentially with a uniformity comparable to sprinklers. (See *Agricultural Research*, June 1981, p. 6, and July/Aug. 1983, p. 8) It has been used with great success and enthusiasm in Idaho and many other western states but has not been adopted in California, where more than 7 million acres of land are under surface irrigation. The major deterrent, particularly in the San Joaquin and Imperial Valleys, is the lack of adequate crossfield slope.

ARS researchers believe they have overcome the problem by attaching a series of goose-necked risers to the pipe's holes.

The original system operates by placing a plug into a pipe that stretches across the field in a carefully graded downward slope. The plug is attached by cable to a feeder reel which pays out the cable as irrigation proceeds. Water, pulled by gravity through the pipe, hits the plug, is backed up and forced out through holes into the furrows. Farmers control the length of time water is applied to a given furrow by adjusting the speed of the feeder reel or a newly developed water brake. (See next story.)

In the system designed for flat fields, the goose-necked risers act as siphon tubes. Because they are staggered in height, they create an artificial grade so that siphon pressure pulls the water through the pipe just as gravity pulls water through a pipe laid out over a sloped field.

"The system is still automated and self-regulating," says Thomas Trout, agricultural engineer at the Snake River Conservation Research Center, Kimberly, Idaho, who designed the siphoning riser tubes. "By putting the slope in the risers, cablegation can be used anywhere, regardless of how level the field is."

Agricultural engineer James Ayars and soil scientist Claude Phene are testing the system at the Water Management Research Laboratory in Fresno, Calif., in cooperation with Murrieta Farms. Says Ayars, "Our system will have larger flow rates and greater discharge (20 gallons per minute per furrow instead of 10) than the ones that have been used in Idaho."

The scientists are studying the modified cablegation system along with three other types of irrigation on 150 acres. Three 26-acre plots are devoted to a conventional siphoning system, while the remaining three 26-acre plots are under a trickle irriga-

Cablegation "Brakes" From the Conventional

A water brake requiring no power source and very little maintenance has been developed to replace the electric motor and clocking device that previously controlled water applications in cablegation systems.

Designed by agricultural engineer Dennis C. Kincaid at Kimberly, Idaho, the water brake costs about the same to install but is more convenient to use than the motor-driven system. The latter is powered by an automobile battery that requires recharging. The water brake operates on basic hydraulic principles, he says, and provides cablegation users more flexibility than ever before.

Until now, the rate at which the feeder reel paid out the cable has been governed by a geared-down electric motor and clocking device. Reel speed was independent of water pressure on the plug.

Kincaid's water brake, however, is dependent on feedback for control. Reel speed depends on cable tension,

tion system using saline water, a surge system using conventional gated pipe, and the cablegation system.

"All of the systems are being tested concurrently and all will be used on cotton, sugarbeets, and small grains," says Ayars, "but our intention is not to compare them so much as to evaluate their potential for water management in the San Joaquin and Imperial Valleys."

"There's a place for every irrigation system in the Valleys," says Phene; "that's why we study all of the options."

Thomas Trout is located at the Snake River Conservation Research Center, Rt. 1, Box 186, Kimberly, Idaho 83341. James Ayars and Claude Phene are located at the Water Management Research Laboratory, 5544 Air Terminal Dr., Fresno, Calif. 93727.—**Lynn Yarris,** Oakland, Calif. ■

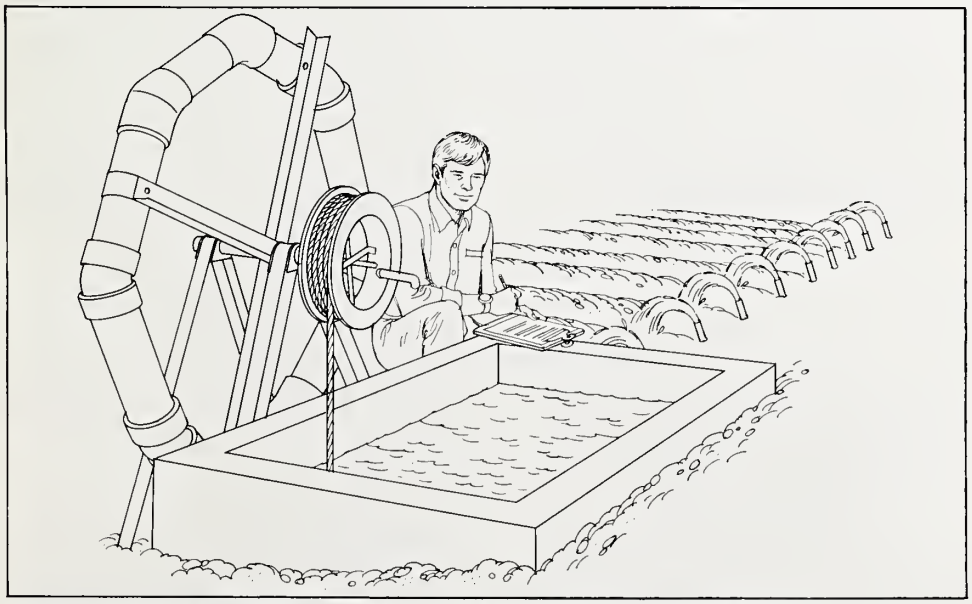
At Murrieta Farms, Fresno, Calif., Ayers adjusts feeder reel and plug of the cablegation system modified for flat fields. The system employs goose-necked risers adjusted in height to allow continuous flow as on a sloped field. (1083X1480-6)

which, in turn, depends on the force of the water on the plug.

"This brake is actually an energy dissipater," says Kincaid. Depending on feedback for control enables the brake to compensate for changes in water flow as the plug moves down the pipe, also for changes in pipe slope midway through a run, and for any changes in furrow length.

"Control won't be quite as precise as with a motor-controlled reel," says Kincaid. "Payout speed will vary a little, but not enough to be significant."

Kincaid's water brake consists of two water-holding chambers of plastic piping mounted on a vertical rotating frame (see diagram). The two chambers are connected by valves to form a closed loop. The brake can be constructed with sections of black plastic sewer pipe or polyvinyl chloride pipe joined together to form an octagonal or circular shape.



As its name implies, the waterbrake uses the torque of a "liquid wheel" to control the rate at which a cablegation reel unwinds. (PN-7113)

The brake is about half filled with water and attached to the feeder reel by a horizontal shaft. Water pressure on the plug produces tension on the cable, which, in turn, applies torque to the feeder reel and the shaft. As the water brake begins to rotate, the water inside continually flows from one chamber to the other to counterbalance the torque. By adjusting the valve openings, the brake can be set to handle any desired range of cable speed, or to stop cable movement altogether.

By using a calcium chloride salt solution or antifreeze in the chambers, the brake can be left out in the field all year round. Because the salt solution is heavier than water, it increases torque on the shaft by 30 percent. This means the brake can be smaller in size.

Kincaid says a local machine shop has already built several brakes, and a few have been shipped to other states.

Dennis C. Kincaid is located at the Snake River Conservation Research Center, Rt. 1, Box 186, Kimberly, Idaho 83341.—**Lynn Yarris,** Oakland, Calif. ■

Proper Feedlot Construction = No Pollution

Cattle feedlot operations need not pose a threat to ground water quality if properly constructed, according to soil scientist Fred A. Norstadt.

He constructed a feedlot that holds the offending pollutants from animal wastes in the surface layers of soil until the chemicals break down into harmless forms. The major pollutants are organic matter, nitrate nitrogen, and salts.

The nonpolluting feedlot was built on 18 inches of sand over 54 inches of clay loam soil near Fort Collins, Colo. It retained salts and retarded nitrogen movement downward to ground water. With proper management, such construction would be effective for up to 100 years, Norstadt believes.

The design was more effective in preventing potential ground water contamination than clay loam over sand, all clay loam, or all sand, he says. A feedlot built over a coarse-textured, sandy loam soil might allow some seepage of salts and nitrogen.

"The superiority of sand over clay loam may be because the pollutants move through the sand layer, then stop at the clay loam layer where oxygen deficiency enhances breakdown of mineral nitrogen to harmless forms," says Norstadt.

When starting a cattle-feeding operation, proper location of the feedlot should be the first consideration. Soil surveys can indicate where sand naturally occurs over clay loam or where a suitable area can be created by trucking in needed materials. The feedlot should have about a 1½-foot drop per 100-foot run.

After the feedlot is built, management is the most important factor in pollution control. At least 4 inches of manure should be left on the surface at all times. If cattle start to dig holes in the manure pack, the holes should be promptly filled to prevent enlargement. This ensures slower infiltration, which favors nitrogen breakdown.

Norstadt and agricultural engineer Harold R. Duke measured water content, acidity, ammonium nitrogen, nitrite nitrogen, nitrate nitrogen, electrical conductivity (a measure of soluble salts), and orthophosphate in the soil layers beneath the feedlots. The feedlots were located in a semiarid climatic zone with an average annual precipitation of 14 inches. The scientists say results may vary in other regions.

Fred A. Norstadt is located at P.O. Box E, Federal Bldg., Fort Collins, Colo. 80522. Harold R. Duke is located at the Agricultural Engineering Research Center, Colorado State University, Fort Collins, Colo. 80523.—**Dennis Senft,** Oakland, Calif. ■

Wasting Away

Animal waste is a euphemistic expression for what is actually a vast resource, says ARS agricultural engineer Conrad B. Gilbertson at Lincoln, Nebr. He calculates that about 1½ billion tons result from domestic animal production in the United States every year.

If it were possible to process all of this resource for other uses, it would result in enough nitrogen fertilizer for 42 million acres of cropland at a rate of 200 pounds per acre. It also contains enough crude protein to feed about 140 million feedlot steers for 180 days and the energy equivalent to 11 billion gallons of gasoline.

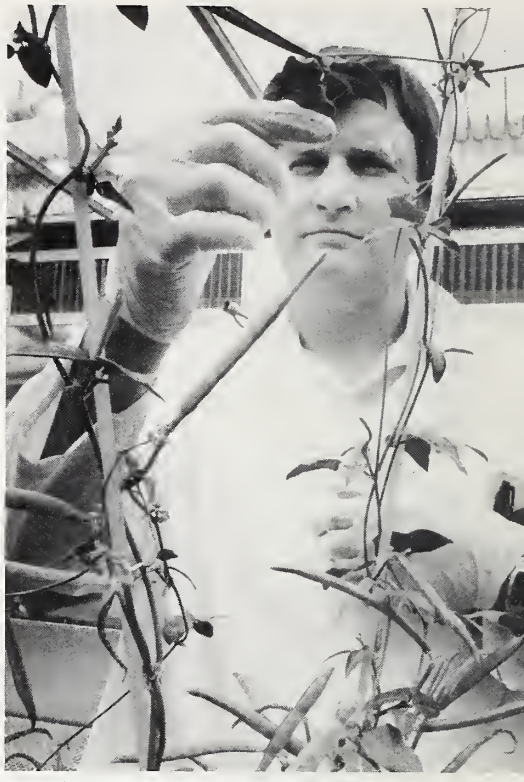
Many factors limit the feasibility of these uses, however. About half of the manure is deposited on land by grazing animals and thus is unretrievable. ■

Plant Scientists Plug Nickel Into Essential Category

The latest botanical secret revealed by science is that green plants may need minute amounts of the mineral nickel for their health and well-being.

Nickel is the first chemical element shown to be essential to plants since 1954 when scientists discovered that chlorine plays an essential role in photosynthesis—the process by which plants use energy from light.

According to new findings at the Plant, Soil, and Nutrition Laboratory in Ithaca, N.Y., nickel is essential for normal nitrogen metabolism in soybeans,



Plant physiologist Ross M. Welch observes leaflet dieback in nickel-deficient cowpeas. (PN-7114)

cowpeas, and possibly all higher plants. Experiments on plants growing in water-nutrient culture, or hydroponics, show that nickel may also play a role in helping plants resist diseases.

"No immediate impact on fertilizer industries can be expected because we don't know if nickel-deficient soils exist," says plant physiologist Ross M. Welch. "But, we have discovered that a nitrogen cycle in plants, previously thought to be unimportant, may help us better understand how plants make use of nitrogen." Research associate David L. Eskew of Cornell University, Welch, and ARS research chemist Earle E. Cary conducted the study.

They built their experiments upon the recent discovery that nickel is a part of urease—the plant enzyme that breaks down the nitrogen compound urea into simpler compounds that, in turn, aid growth and development. Eskew, Welch, and Cary showed that without nickel, plants do not properly metabolize urea, which they obtain from fertilizers, nitrogen-fixing bacteria,

or other natural phenomena. Plants deprived of nickel accumulated toxic levels of urea in leaves, causing dieback or leaf tip necrosis. They will repeat their experiments on water-cultured barley, wheat, and other plants.

Sixteen elements are currently recognized as being universally essential to plants. Major nutrient elements are carbon, hydrogen, and oxygen which are readily available to plants from water and air; and calcium, magnesium, potassium, nitrogen, phosphorus, and sulfur which are common constituents of fertilizers. If further research confirms the new findings, nickel will join a group of seven minor nutrient elements: iron, manganese, boron, copper, zinc, molybdenum, and chlorine.

The minor elements usually serve plants as catalysts for chemical reactions that require minute amounts. They are widely distributed in soil. However, agriculture must often deal with soils in some areas of the world where certain minor nutrients are lacking or in short supply.

Ross M. Welch and Earle E. Cary are located at the U.S. Plant, Soil, and Nutrition Laboratory Bldg., P.O. Box 849, Tower Rd., Ithaca, N.Y. 14853.—**Stephen Berberich,** Beltsville, Md. ■

CO_2 Speeds Root Growth of Cuttings

Enriching greenhouse atmospheres with carbon dioxide (CO_2) can, for many plants, cut the time needed to obtain large, well-rooted cuttings, a recent ARS study has shown.

Tests on cuttings from eight horticultural nursery crop species representing seven families demonstrated that added CO_2 accelerates cutting root growth for five of the species. The tests were conducted by plant physiologist John R. Potter, Corvallis, Oreg., and horticulturist Tim D. Davis, now with Brigham Young University, Provo, Utah. They included foliage plants and flowering shrubs.

Many horticultural crops, including most woody ornamentals, apples, pears, and small fruits, are propagated by rooting cuttings in order to maintain their genetic or varietal purity.

The Corvallis researchers found that for the majority of crops they tested, CO_2 enrichment promoted either the number of roots per cutting or root weight per cutting. Though rooting was eventually virtually 100 percent for both enriched and normal atmospheres, and there were few differences in post-rooting growth for both treatments after 4 weeks, roots consistently emerged 1 or 2 days earlier in the enriched atmosphere.

The tests were conducted as part of a broad, ongoing study to determine how photosynthesis is related to rooting and whether rooting can be stimulated by stimulating photosynthesis.

Atmospheric CO_2 levels influence photosynthesis—the higher the level, the greater the rate of photosynthesis. Through photosynthesis, plants make carbohydrates, which serve as fuel for their growth. The idea was that stimulating photosynthesis would increase plant carbohydrate production, which, in turn, would enable the plant to root faster and to make more and larger roots.

In their tests, however, Potter and Davis found indications that carbohydrate production reaches a point of diminishing return, where further stimulation no longer affects rooting. Some of the improved rooting, they say, might have come from the ability of CO_2 enrichment to improve plant water use.

Says Potter, "We can say if photosynthesis is inhibited, rooting will probably be inhibited."

John R. Potter is located at the Horticultural Crops Research Laboratory, 3420 S.W. Orchard Ave., Corvallis, Oreg. 97330.—**Lynn Yarris,** Oakland, Calif. ■

Not All Seed Stores the Same

Seed from the same plant species or cultivar may appear to be identical, but some seed can be stored longer before it loses its ability to germinate.

Apparently, evolution and, more recently, plant breeding have changed the storability of various seed, says plant physiologist Louis N. Bass, at the National Seed Storage Laboratory, Fort Collins, Colo. He tested reed canarygrass seed that had been stored for up to 18 years in the lab's temperature- and humidity-controlled rooms. The seed did not germinate equally well.

The environment in which a plant grows affects how long seed can be stored. Seed harvested from the same plant in two different years did not germinate equally well.

The length of time that seed can be stored is also determined by how gently it is handled during harvest and cleaning, and then by the temperature and relative humidity in the storage area.

In this experiment, Bass stored seed at either 50, 41, 30, or 10° F. Seed germinated best when stored at the lower temperatures.

Louis N. Bass is located at the National Seed Storage Laboratory, Colorado State University, Fort Collins, Colo. 80523.—**Dennis Senft,** Oakland, Calif. ■

Breeding Nematode-Resistant Alfalfa

The root-lesion nematode, *Pratylenchus penetrans,* is guilty of reducing yields of legumes in Canada, causing failure of alfalfa seedlings in Kentucky, and appears to decrease cold tolerance and increase occurrence of plant diseases in alfalfa.

Scientists at the University of Minnesota's North Central Experiment Station at Grand Rapids recently recognized the tiny roundworm as a serious problem in that state. Graduate student David L. Nelson, ARS research geneticist Donald K. Barnes, and University of Minnesota plant pathologist David H. MacDonald took advantage of the infestation at the station to develop methods to screen alfalfa plants for resistance to the nematode.

They selected vigorous plants from a severely damaged plot of 2-year-old alfalfa cultivars that survived in spite of a nematode population of more than 800 in each 4 cubic inches of soil. They intercrossed the selected plants, screened the progeny for resistance, and followed up with a second round

of field selection. They then inoculated the survivors with root-lesion nematodes and evaluated them in controlled growth chambers and the field.

Some of the new plant materials showed greater stand establishment, better shoot and dry-weight production, and lower numbers of nematodes in the roots than the original plant material.

"Even though significant progress has been made in selecting for resistance," Barnes says, "the current level of improvement is not enough to completely overcome the high nematode numbers at Grand Rapids without protection by nematicides. The level of resistance may be adequate for less severe conditions, and it should help plants remain productive after nematicide treatment assists in establishing a seeding."

These results are significant not only because they demonstrate that *P. penetrans* seriously affects alfalfa performance, but also because they show a variability in resistance among alfalfa lines, Barnes says. Results were similar in both growth chamber and field evaluations.

The evaluation methods can be used in breeding programs to improve resistance to root-lesion nematode. Cultivars with increased resistance could be useful in increasing stand establishment and forage yield in many areas of North America.

Donald K. Barnes is located in Rm. 404, Agronomy Bldg., University of Minnesota, St. Paul, Minn. 55108.—**Ray Pierce,** Peoria, Ill. ■

Cattle Can Be Finicky Eaters

When cattle graze they are making selections for their diets—carefully eating some grasses and ignoring others. Now, scientists have discovered that these animals clearly prefer fertilized grasses over unfertilized grasses.

If this preference is strong enough, cattle might be enticed to wander considerable distances to eat these better-tasting grasses, thus more efficiently utilizing rangelands, says botanist Marilyn Samuel, Cheyenne, Wyo. Cattle normally graze close to their source of water.

She suggests that if ranchers have mixed-grass areas on their rangeland where cattle are not grazing, they might try fertilizing in an effort to spread their livestock more evenly. The cattle she observed in this 3-year study preferred grasses that receive 20 pounds of nitrogen per acre each spring.

Nitrogen increased plant growth and crude-protein content and made the grasses tastier. However, Samuel says, the increased forage yields were not enough in themselves to justify the expense for fertilizer and the time and energy to apply it. Her observation is based on previous work by ARS soil scientists Frank Rauzi and Merle L. Fairbourn, now retired.

Samuel cautions ranchers that the mixed-grass areas should be fairly free of less desirable annual plants and especially weeds. Fertilizer doesn't discriminate; all plants benefit from its application.

Marilyn Samuel is located at the High Plains Grasslands Research Center, 8408 Hildreth Rd., Cheyenne, Wyo. 82009.—**Dennis Senft,** Oakland, Calif. ■